MANAGERIAL EFFICIENCY, ORGANIZTIONAL CAPITAL AND PRODUCTIVITY

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Abstract

The paper focuses on the impact of managerial efficiency on output. Three sources of managerial efficiency are identified: (a) superior initial managerial endowments, (b) the accumulation of managerial knowledge and skills through learning and (c) the impact of an effective market for managerial resources internal to the firm. All three are explicitly measured by appropriate variables and their impact is examined in the context of variously specified production functions. The empirical analysis is carried out with data for approximately 5,000 new manufacturing plants in the United States over the 1973-92 period. It is found that variation in managerial endowments is an important explanatory variable for output with all other relevant inputs controlled. It is further found that the survival of plants with superior managerial efficiency, and the death of those with inferior efficiency, explains a substantial fraction of total factor productivity change in the manufacturing sector of the U.S. economy. There is also clear evidence of the significance for efficiency of internal markets as well as evidence of learning as plants age. Learning and superior managerial resources of old plants largely offset the benefits of capital goods of later vintage of new plants.

Key words: Managerial efficiency, organizational capital, productivity.

JEL Classification: D24, L23, O30.

Among the principal contributions of work on technical change in the last several decades has been a narrowing of the scope of the "black box" in productivity measures. The black box encompasses "total factor productivity change" and depends either on incomplete identification of inputs or on the measurement of identified inputs in different efficiency units. For if all inputs are identified, and if all are measured in consistent efficiency units, total factor productivity change must by definition be zero. In effect, we will have ascribed all changes in productivity to the sources of such change.

The first major breakthrough in this direction was the attempt to convert labor inputs into equivalent productivity units by Jorgenson and Griliches (1967). Next came several attempts to do the same for capital, at the macro level by Hulten (1992) and Greenwood, Hercowitz and Krusell (1997), and at the micro level by Bahk and Gort (1993). More recently, discussion has focused on organizational capital as an overlooked input. The concept has a long history in the literature of industrial engineering but was first introduced in economics by Prescott and Visscher (1980). We now focus on differences in managerial efficiency as another input which, in some sense, may be viewed as a component of organizational capital.

Assuming efficient markets with perfect information and perfect competition in bids for managerial talent, such talent may be viewed as an asset the price of which will capture the rewards of all differences in its quality. However, even before the days of Enron and Tyco, there were questions about whether managerial compensation does not sometimes appropriate the returns to capital, if not capital itself. Conversely, the value of superior managerial talent may not be fully captured by managerial compensation for two reasons. First, information on the contribution of differences in managerial skills to earnings or productivity is usually highly imperfect. Second, superior managerial ability may be firm specific, that is, associated with the unique attributes of the firm and, hence, not subject to competition for talent that equates the price of superior talent to its value.

Differences in managerial ability not reflected in compensation to managers may be subsumed as components of the firm's organizational capital. It is important, however, to identify the separate effects of this variable. The paper focuses on several principal questions. First, it develops an independent measure of the quality of managerial endowments. Second it attempts to measure for the first time the impact of superior managerial endowments on productivity at the plant level. Third, it uses the microeconomic estimates to generate estimates of the effect of survival of plants with superior managers on the productivity of the manufacturing sector in the United States. Fourth, it compares the benefits of managerial learning through experience of old plants with the benefits of later capital goods of new plants.

I. The Framework for Identifying the Effect of Managerial Efficiency

Our approach entails identifying the effect of managerial efficiency, viewed as an initial endowment of a firm or plant, on output. We do so after controlling for the effects of all other variables that influence output. This requires first that we fully specify a production function in which initial managerial endowments are an argument and, second, that we develop a measure of such endowments.

We start with a simple production with three inputs: labor L, physical capital K and organizational capital Φ.

$$Y_t = F(L_t, K_t, \Phi_t), \tag{1}$$

where Y denotes output and subscript t denotes chronological time in years. We next decompose Φ_t into three arguments: (a) knowledge accumulated over time, that is, organizational learning a, (b) initial managerial endowments E and (c) other forms of intangible organizational endowments M, of which the existence of a market internal to the firm for managerial resources is dominant. Thus

$$\Phi_t = \theta(a_t, E_t, M_t), \tag{2}$$

where $\partial\theta / \partial a > 0$. $\partial\theta / \partial E > 0$ and $\partial\theta / \partial M > 0$.

One aspect of organizational capital, or managerial efficiency, is accumulated through experience over time. Such accumulation encompasses (a) information that permits the screening of new recruits as well as more effective matching of workers and tasks, (b) managerial coordination for interdependent tasks including the matching of employees with complementary knowledge and skills, (c) experience that improves information on the effective capacity of machines and the efficient use of all capital goods, and (d) the routinization of tasks that, as pointed out by Penrose (1959), reduces the required level of managerial skills for a given output. Such accumulation of organizational capital may be proxied, as proposed by Oi (1967) and Fellner (1969), by the age of the organization.

As distinct from the stock of accumulated knowledge over time at the firm or plant level, we have differences in initial managerial and entrepreneurial endowments. These initial differences in endowments may persist for long spans of time since the successors of managers and entrepreneurs will in large part be determined by their predecessors.

Finally, we have the third category consisting of other organizational endowments. There is no general agreement in economic literature on which organizational attribute is dominant. For example, does it make a difference if the firm is centralized or decentralized, if labor is organized into teams, if there is functional or divisional organization (an issue raised by Williamson (1975)), etc. However, we hypothesize that of dominant importance is the existence of markets internal to the firm in the allocation of intra-firm resources. This is particularly critical in the allocation of managerial resources. The existence of options internal to the firm for the use of managers, we conjecture, raises the efficiency with which such managers are used relative to organizations in which the options are limited to continued use in the same tasks or dismissal. Indeed, even when managers are transferred across firms, there is often no opportunity to transfer much of managerial experience, some of which is firm specific, except perhaps through mergers and acquisitions of entire firms.

We are now ready to expand the production function further by the addition of variables that (a) capture the quality of labor, or human capital, and (b) the quality of physical capital. Moreover, we must allow for the fact that knowledge and, hence, technical change is accumulated over time not only at the plant or firm level but also at the economy-wide or industry-wide level. Accordingly, our new production function is

$$Y_{it} = A_t \theta(a_{it}, E_{it}, M_{it}) F(L_{it}, H_{it}, K_{it}, V_{it}), \tag{3}$$

where A_t is a shift parameter for industry-wide or economy-wide accumulation of knowledge at time t while all other variables are related to plant i at time t. Thus a_{it} is organizational learning, E_{it} managerial endowments, M_{it} organizational endowments, L_{it} pure labor, H_{it} human capital or the quality of labor, K_{it} physical capital and V_{it} the quality of physical capital. All variables with the exception of A_t, which is simply time dependent, are associated with explicit measures to be discussed later. Thus only A_t remains as a component of the former black box which, in some production functions, encompasses the effects of all the above variables with the exception of L and K. We now specify equation (3) in Cobb-Douglas form,

$$Y_{it} = A_t \theta(a_{it}, E_{it}, M_{it}) L_{it}^{\beta_l} H_{it}^{\beta_h} K_{it}^{\beta_k} V_{it}^{\beta_v} \tag{4}$$

II. The First Empirical Specification

Our first task is to generate a measure of the quality of managerial endowments E_{it}. We do so by assuming that superior managerial ability leads to a higher probability of survival for a firm or plant and, hence, a longer expected life. Thus, we proxy managerial ability by post hoc evidence on the actual length of a plant's life. Since we focus on the relation of this variable to the productivity of the plant, an obvious question is whether survival belongs on the left rather than the right hand side of the equation. In the context of both the model and the data used, we believe for reasons given below that a specification in which survival is an explanatory variable is correct.

First, our data consist of cross sections of manufacturing plants across many industries. There is no reason why differences in cost (productivity) across industries should affect survival. Steel does not compete with shoes nor the latter with men's outerwear. On the other hand, managerial ability determines survival and affects the efficiency of production. Second, even within the same industries, survival depends not merely on costs but on other dimensions of managerial decisions such as marketing, gauging demand, producing a product that consumers want, etc. Third, our empirical specification does not deal with concurrent variations in costs and survival. It is rather a fixed effects model in which we estimate the consequence of attaining various thresholds of future survival up to 25 years after the birth of the plants, for the initial productivity of these plants just after their birth. If differences in initial costs were critical to survival, one would expect that effect to show up in consequences for survival very rapidly.

A problem with a fully specified production function is that some of the variables are to some extent collinear. For example, in equations (3) and (4) the age of the plant is likely to be inversely related to the quality of capital if the latter is proxied by its vintage, with older vintages signifying inferior capital. Similarly, the shift parameter A_t representing industry-wide learning may be positively related to the quality of the capital and negatively to the age of the plant. And, of course, older plants will have had an opportunity to survive longer than recently born ones. To simplify the analysis, therefore, we estimate plant production functions at a common point in time, namely shortly after their birth. This is carried out for several cohorts of plants based on year of birth. The resulting cross-sections permit us to drop out A_t, a_{it} and V_{it} in equations (3) and (4) since all observations are identical with respect to the three variables. Accordingly, equation (3) is simplified to (5) below.

$$Y_{it|a=1} = \theta(E_{it|a=1}, M_{it|a=1}) L_{it|a=1}{}^{\gamma_l} H_{it|a=1}{}^{\gamma_h} K_{it|a=1}{}^{\gamma_k} . \qquad (5)$$

The initial productivity of plants thus depends on managerial endowments, organizational endowments, labor and its quality and the capital stock.

Managerial endowments are measured by the duration of a plant's survival recorded at successive five-year intervals. The empirical specification of fixed effects associated with successive thresholds of survival permits us to examine the effects of various durations of survival (managerial endowments) on productivity at birth.

We then test the following specification with the fixed-effects of various survival intervals:

$$\log Y_{it1a=1} = \gamma_0 + \Sigma_j \gamma_{ej} E_{itj|a=1} + \gamma_m M_{it|a=1}$$

$$+ \gamma_l \log L_{it|a=1} + \gamma_h \log H_{it|a=1} + \gamma_k \log K_{it|a=1} + u_{it|a=1}, \qquad (6)$$

where E_j (for $j = 2,3,4,5$) indicates endowment fixed-effects. Each E_j is categorical with a value of 1 if a plant operates for j five-year intervals and 0 otherwise, and the remaining variables are as defined for equation (5). The coefficients of γ_{ej}, for $j = 2,3,4,5$, measure the independent effects of managerial endowments on productivity change associated with each survival interval. Because the dummy for E_1 is used as a baseline and dropped in the equation, each γ_{ej} captures the proportional changes in plant productivity for each survival interval relative to the first.

We have yet to explain the measures of M, L, H and K. M, which captures the opportunities for reallocating managerial resources within the firm, is first proxied as a categorical variable which shows whether a plant belongs to a single-plant or multi-plant firm (in short, whether there is an opportunity for reallocating managerial resources across plants owned by the same firm). An alternative specification used for this variable is product diversification. That is, a categorical distinction is made between plants that belong to firms that operate plants in more than one industry and those that do not. The possible effect of such diversification on productivity is discussed in Jovanovic (1993). Of course, product diversification is only one of the forms of diversification captured by multi-plant organization. Others are geographic diversification, diversification in the quality and combinations of inputs used, in the quality of products produced, etc. All provide opportunities for intra-firm resource reallocation.

L is measured by number of employees and K by cumulative gross investment. Since investment (K) is the initial investment of the plant, it does not vary with respect to vintage and is, therefore, assumed to be of homogenous quality. In contrast, there are large cross-sectional variations across plants in the quality of labor used. The skills and physical attributes of labor that affect productivity are expressed in common efficiency units through prices. By assuming competitive labor markets, we infer that wage differences measure the differences in the marginal products of labor.

The use of wages as a measure of human capital is especially appropriate in the context of cross section data since such factors as skill biased technical change are automatically excluded. Moreover, as shown in Gort and Lee (2001a), regional variations in the price of labor cannot plausibly explain the observed inter-plant variations in wages. Our approach to measurement of human capital has several advantages over the currently more common use of education as a proxy. First, workers acquire their education at different times. Since education is itself subject to technical change, equivalent years of schooling do not yield equivalent skills. Second, as shown by Mincer (1974), income and, hence, productivity depend heavily on experience. Third, even with training measured at a common point in time, broadly defined educational backgrounds (e.g. years of schooling) are not homogenous in their impact on productivity.

III. Data and First Estimates

The estimates were initially carried out with three cohorts of newly born plants drawn from the U.S. Census Bureau's Longitudinal Research Database. The three cohorts encompassed the years 1973-75, 1977-79 and 1982-84 and consisted, respectively, of 1,854, 1,586 and 456 plants.[1] Each cohort combined births over three years, rather than one, to increase sample sizes without deviating much from the objective of estimating production functions from data on inputs and output at common points in time for all plants. To allow for sufficient time for all inputs to be phased in and initial construction completed, so that input-output relations are estimated at the production frontier, production functions were estimated for the third year after birth.

The first three columns of Table 1 present the results for equation (6) and strongly support the hypothesized relations. Almost all the coefficients are associated with fairly high t-values and are significant at the 1% level. In particular, firms that survive longer -- that is, have superior managerial endowments -- are markedly more productive in their initial year of operations. The average impact on initial output of surviving ten rather five years ranges from 1.8% to 3% for each additional year of survival. That for surviving 15 years yields an additional 1.5% to 6% for each extra year of survival past ten and an additional 1.2% to 4% per year for surviving past fifteen to year twenty. By year twenty-five, however, the beneficial effect declines relative to shorter survival intervals. Thus, it

[1] We started with all plants that were coded as new by the Census Bureau. However, to assure that only truly new plants were included in the sample, we excluded all plants for which cumulative capital expenditures in the first three years were less than 75% of the plants' fixed assets at the end of those three years. Plants with discontinuous records were also excluded. The disappearance of a plant in a year between Censuses was in all instances verified at the next Census year to assure accuracy of survival data.

Table 1

Production Functions for Three entry Cohorts and for Entry in 1973-82, With Fixed-Effects of Survival as in Equation (6)*

Variables	Entry in 1973-75	Entry in 1977-79	Entry in 1982-84	Entry in 1973-82
Constant	1.4734	1.6765	1.5701	1.4552
	(16.17)	(18.88)	(7.43)	(23.53)
Vintage				0.0205
				(4.95)
E_2	0.1601	0.1236	0.0877	0.1564
	(3.36)	(3.04)	(1.01)	(5.72)
E_3	0.4103	0.1997	0.3931	0.3314
	(4.55)	(2.80)	(2.85)	(7.16)
E_4	0.6213	0.2608		0.4921
	(5.55)	(2.19)		(6.98)
E_5	0.3756			0.3511
	(2.65)			(2.22)
Log (L)	0.6928	0.8183	0.7434	0.7691
	(39.46)	(51.85)	(18.94)	(76.29)
Log (W)	0.7769	0.9579	0.6500	0.8587
	(18.87)	(25.49)	(7.27)	(35.72)
Log (K)	0.1656	0.1382	0.1344	0.1447
	(10.71)	(10.44)	(4.04)	(16.83)
Multi-unit	0.4213	0.1953	0.2345	0.2903
	(9.16)	(4.44)	(2.16)	(10.40)
R-square	0.84	0.86	0.74	0.85

* Heteroskedasticity-corrected t-values are in parentheses. Dependent variable (measuring output) is log of value of shipments. E_j, for $j = 2,3,4$ and 5, represents survival for successive five year intervals. For the other explanatory variables, L, W, and K denote total employment, average wage for the plant and cumulative capital expenditures. Vintage is given a value of 1 for 1973 investment and successively higher values for later years' investment. The sample consists of 1,854, 1,586, 456 plants for 1973-75, 1977-79 and 1982-84 entry cohorts, respectively, and 4,727 plants for entry in 1973-82.

appears, the benefits of superior initial managerial endowments eventually decline -- a conclusion consistent with (a) the finite working life of initial managers and (b) the chance element in the selection of successors. The existence of a multi-establishment organization enhances sharply plant productivity, consistent with our hypothesis. The effect, however, which ranges from 20% to 40% intuitively seems too high to attribute exclusively to resource reallocation and may capture the effects of other variables complementary with multi-unit organization.

IV. Alternative Specifications

Column (4) in Table 1 shows the results on a similar basis but with all births of plants in the 1973-82 period combined, yielding a sample 4,727 plants. Since the observations no longer refer to narrowly defined cohorts, we must take into account the fact that the fixed capital of plants now differs in quality. This requires us to introduce an index for the quality of capital, V_{it}, which we add to equation (6). A conventional theoretical approach, though one used infrequently in empirical studies, would measure the quality of capital as hedonic indexes based on prices. Because of absence of concurrent price data for capital of different quality, we measure the quality of capital by vintage. It is presumed to capture the effect of all obsolescence. We therefore apply the weighted average vintage to gross capital stock, rather than to net assets, since obsolescence explains most of the difference between gross and net stocks.

More specifically, we assume that each vintage is associated with a unique best practice technology, and the efficiency of a plant's stock of capital V_{it} is a function of the average vintage of the stock, that is $V_{it} = V(v_{it})$ where v denotes the average vintage of the stock of plant i at time t. We therefore specify the following:

$$V_{it} = e^{\lambda_K v_{it}}, \tag{7}$$

where $\lambda_K > 0$ is a parameter that reflects productivity enhancement attributable to vintage and is used to convert capital into common efficiency units.

The results for the larger sample of 4,727 plants are very similar to the average for the 1973-75 and 1977-79 cohorts in Table 1. The only important addition is the effect of vintage that points to a 2% change in output for each one-year change in weighted average vintage. Vintage is given a value of 1 for 1973 investment and successively higher values for later years.

Table 2 tests equation (6) with alternative measures of key variables for the 1973-75 and 1977-79 samples of 1,854 and 1,586 plants, respectively. Estimates for the much smaller sample for 1982-84 were not carried out this time. More specifically, the following modifications were introduced:

(a) A product diversification measure based on whether the plants of the firm were limited to one or more than one industry was substituted for multi-establishment organization. Because the two variables are closely related, they cannot both be introduced concurrently.

(b) The relation between output and average wages is specified in linear rather than log-linear form since there is no clear a priori basis for choosing between the two.

(c) For those who may view the separation of "pure labor" and human capital artificial,

Table 2

Alternative Specifications of Equation (6) for 1973-75 and 1977-79 Birth Cohorts*

Variables	Entry in 1973-75					Entry in 1977-79				
	(i)	(ii)	(iii)	(iv)	(v)	(i)	(ii)	(iii)	(iv)	(v)
Constant	1.5311	-0.8075	1.2762	-0.8043	1.3237	1.7213	-0.9828	1.3839	-0.9855	1.4149
	(16.64)	(-13.68)	(34.34)	(-13.65)	(39.30)	(19.41)	(-16.61)	(41.76)	(-16.76)	(44.27)
E_2	0.1375	0.1638	0.1583	0.1410	0.1378	0.1172	0.1309	0.1249	0.1239	0.1181
	(2.74)	(3.18)	(3.09)	(2.74)	(2.69)	(2.88)	(3.06)	(3.09)	(2.88)	(2.92)
E_3	0.4078	0.3946	0.3893	0.3876	0.3853	0.2014	0.2181	0.2114	0.2229	0.2147
	(4.98)	(4.60)	(4.86)	(4.46)	(4.78)	(2.78)	(2.81)	(3.00)	(2.81)	(2.99)
E_4	0.6177	0.5715	0.6058	0.5637	0.6040	0.2696	0.2882	0.2594	0.3002	0.2696
	(5.70)	(5.19)	(5.95)	(4.94)	(5.75)	(2.23)	(2.10)	(2.16)	(2.13)	(2.21)
E_5	0.3804	0.3625	0.3365	0.3702	0.3431					
	(1.88)	(1.66)	(1.75)	(1.65)	(1.75)					
Log (L)	0.7011	0.6986		0.7095		0.8285	0.8101		0.8222	
	(41.82)	(42.64)		(43.06)		(52.21)	(49.43)		(49.91)	
Log (W)	0.7923					0.9761				
	(21.69)					(25.77)				
W		0.0448		0.0464			0.0480		0.0489	
		(18.84)		(19.39)			(36.07)		(36.50)	
Log (WL)			0.7227		0.7338			0.8374		0.8484
			(50.60)		(51.84)			(59.51)		(60.02)
Log (K)	0.1673	0.1756	0.1604	0.1763	0.1615	0.1443	0.1667	0.1383	0.1757	0.1449
	(11.55)	(12.13)	(11.37)	(11.96)	(11.36)	(10.97)	(12.57)	(10.70)	(13.43)	(11.33)
Multi-unit		0.4605	0.4308				0.2481	0.2030		
		(9.73)	(9.32)				(5.34)	(4.65)		
Dvsf	0.3928			0.4236	0.3910	0.1066			0.1389	0.1073
	(8.78)			(9.17)	(8.86)	(2.27)			(2.72)	(2.29)
R-square	0.84	0.83	0.86	0.83	0.86	0.86	0.85	0.87	0.84	0.87

* Heteroskedasticity-corrected t-values are in parentheses. Dependent variable is again log of value of shipments. E_j, for $j = 2,3,4$ and 5, represents survival for successive five year intervals. The explanatory variables, L, W and K denote total employment, average wage for the plant and cumulative capital expenditures, as in Table 1. WL is the total wage bill per plant. Dvsf is diversification where it is 1 if the number of primary 4-digit industries in which a firm's plants operated is more than 1 and 0 otherwise. The sample consists of 1,854 and 1,586 plants for 1973-75 and 1977-79 entry cohorts, respectively.

we combine the two variables into one, namely, the wage bill for each plant.

The results of Table 2 are once again very similar to those of Table 1. The values of the coefficients are of the same order of magnitude and, hence, largely insensitive to changes in specification that we introduced. The much weaker results for the effect of 25-year survival as compared with 20-year survival are consistent with results reported in Table 1. The signs for diversification are positive as for multi-unit organization and the coefficients are, once again, associated with high t-values. For the 1977-79 birth cohort, the coefficients for diversification show a more modest 10-14% effect on output as compared with more than 20% for multi-unit organization. The positive effect of diversification is interesting in the context of the conventional view of the advantages of specialization for efficiency. That is, the benefits of opportunities for intra-firm reallocation appear to be greater than the benefits of specialization. The weaker effect of product diversification than of multi-unit organization is consistent with the fact that the latter also captures other forms of diversification (geographic, input combinations, etc.) in addition to product diversification. Finally, combining the two variables for the labor input ("pure labor" and human capital) into one did not alter the results materially nor did substituting a linear for a log-linear relation between output and average wages.

V. Reintroducing Plant Age and Vintage

An alternative empirical specification of our production function is to examine the relevant relations at a terminal point for our data for new plants, namely 1992. Since, once again, a one-year cross section is considered, industry-wide or economy-wide shifts are excluded by definition. Since plants, however, are born at different points in time, they differ in both age and vintage. While the two variables are partially collinear, such collinearity is limited inasmuch as investment in new plants continues through their entire lives, as shown in Gort and Lee (2001b), with a substantial fraction of cumulative investment occurring after the fifth year of economic life. Because all plants in the sample survived to 1992, there is no survival variable but survival does partially affect the relation between plant age and output. This is because older plants will have, in fact, survived longer than later entrants and some of the latter may not survive after 1992 for equivalent lengths of time. Hence age of plant does not merely measure organizational learning but, indirectly and in part, the variable we have used as a proxy for initial managerial endowments.

Table 3 shows the results for the variables in equation (4) except that the variable for managerial endowments (survival) is omitted. Excluded also is the shift parameter A_t since all observations on output relate to a common point in time. Once again, the effect of product diversification is much weaker than that of multi-unit organization. But the most interesting results, substantively, are the roughly similar magnitudes of the coefficients for age and vintage. In effect, the advantages of more recent vintage are largely (though not completely) offset by the organizational learning and superior management of older plants. It implicitly explains the process which permits older plants to compete with more recent plants using newer technology. Using a different methodology and analytical framework, Jensen, McGuckin and Stiroh (2001) reached a similar conclusion. Stated in another way, the improvement in managerial skills through learning, plus the superior managers of longer surviving plants, offsets much of the

Table 3

Estimates for Production Functions with Plant Age and Vintage, 1992 *

Variables	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Constant	1.2510	1.4266	-0.4755	-0.2711	1.0911	1.2789
	(4.16)	(4.83)	(-1.88)	(-1.12)	(4.20)	(5.12)
Age	0.0178	0.0180	0.0185	0.0187	0.0174	0.0176
	(2.07)	(2.10)	(2.15)	(2.18)	(2.04)	(2.08)
Vintage	0.0238	0.0239	0.0245	0.0246	0.0240	0.0240
	(2.01)	(2.01)	(2.06)	(2.07)	(2.08)	(2.07)
Log (L)	0.6290	0.6290	0.6191	0.6190		
	(30.60)	(30.60)	(30.74)	(30.80)		
Log (W)	0.7207	0.7106				
	(11.08)	(10.97)				
W			0.0262	0.0257		
			(10.78)	(10.61)		
Log(WL)					0.6278	0.6280
					(30.91)	(30.90)
Log (K)	0.2688	0.2724	0.2797	0.2834	0.2782	0.2806
	(13.03)	(13.25)	(13.95)	(14.24)	(14.04)	(14.16)
Multi-unit	0.3156		0.3245		0.3053	
	(3.00)		(3.12)		(2.93)	
Diversification		0.1067		0.1111		0.1032
		(1.79)		(1.86)		(1.73)
R-square	0.76	0.76	0.76	0.76	0.76	0.76

* Heteroskedasticity-corrected t-values are in parentheses. All variables are defined as for Table 2, except for plant age. The latter is simply the number of years since the birth of the plant. The sample consists of 1,114 plants.

advantage of newer capital goods of newer plants. This permits old and new plants to compete on a more even basis than would otherwise have been possible.

VI. Managerial Endowments and Productivity Growth

What is the effect of superior managerial endowments on growth in output in the U.S. economy? That is, what would the effect on growth be if all new firms were protected from competition, or subsidized, and thus were assured of survival? To answer this question requires information on two elements. First, what is the current survival rate, weighted by plant size? Second, what is the effect on output of survival of plants with superior managers and the demise of those with inferior ones? Both classes of information are now available for the manufacturing sector in the United States. As for most broad economic questions, measurement errors are always a problem -- a problem rendered more acute when proxy variables must be used to advance research. Yet the results are sufficiently robust and consistent with theory to justify well defined conclusions even if the estimates must be viewed as only rough approximations.

Table 4 shows the assets at birth of all new plants that survive to each successive Census year as a ratio to assets of all new plants in their cohort. Successive Census years are separated by five-year intervals. Thus, for example, the Table shows that from both the 1972 and 1977 entry cohorts, plants representing 80% of initial assets survived to the next Census years. Plants representing 69% and 66% of all initial assets survived to the second Census for the 1972 and 1977 cohorts, respectively. Actually, the ratios are very stable across cohorts. To enhance reliability, we omitted plant data for small establishments drawn from administrative records rather than from the Censuses.

Table 4

Initial Assets of New Plant Survivors to Initial Assets of All New Plants for Various Entry Cohorts*

Entry Year	Initial Asset Ratio for			
	$S_{1977,t}$	$S_{1982,t}$	$S_{1987,t}$	$S_{1992,t}$
1972	0.80	0.69	0.56	0.48
1977		0.80	0.66	0.57
1982			0.75	0.62
1987				0.78

Source: Based on data from Longitudinal Research Database

* $S_{t+5j,t}$, for j = 1,2,3,4 and 5, denotes the initial asset ratio for plants that exist in the market for at least j Census years after they were born in year t and the denominators of the ratios are the initial assets of all plants in the cohort..

Table 5

Estimates of Reduction in Growth in Output, Holding Inputs Constant, If All New Plants Survived for Successive 5-year Intervals*

Entry Year (t)	Survived Census (j)	Inefficiency ($Q_{j,z,t}$) for				Weighted Inefficiency ($I_{j,t}$)
		z=1	z=2	z=3	z=4	
1972	j = 1	0.0320	0.0821	0.1241	0.0751	0.060
	j = 2	0.0344	0.0634	0.0296		0.030
	j = 3	0.0398	-0.0065			0.00006
	j = 4	-0.0351				-0.030
1977	j = 1	0.0247	0.0399	0.0522		0.037
	j = 2	0.0133	0.0240			0.019
	j = 3	0.0083				0.007
1982	j = 1	0.0219	0.0983			0.064
	j = 2	0.0529				0.044

* Based on equations (8) and (9) in the text. Inasmuch as data beyond 1992 were not available, we assume that $S_{1997+\tau,t} = 0$, for $\tau \geq 0$, to facilitate the calculation. The coefficients corresponding to $E_{j,t}$ for each cohort, 1973-75, 1977-79 and 1982-84 are then applied, respectively, to 1972, 1977 and 1982.

However, even the inclusion of such plants does not change statistics on survival very much. In short, the information on survival seems fairly firm.

Our next step is to combine data in Table 4 with the coefficients for the fixed effects of survival based on Table 1. The appropriate formulas are given by equations (8) and (9).

$$Q_{j,z,t} = \frac{S_{t+5(j-1),t} - S_{t+5j,t}}{S_{t+5(j-1),t}} \left(\gamma_{j+z,t} - \gamma_{j,t} \right), \tag{8}$$

where $Q_{j,z,t}$ is an unweighted index that measures the loss in output per unit of combined inputs that would occur if a given set of inefficient plants that survived the j^{th} Census year following their birth at t had retained their market share for an additional z Census years. $\gamma_{j,t}$ is the coefficient of $E_{j,t}$ in Table 1 and captures the relative efficiency of surviving plants. S denotes the initial asset ratios as shown in Table 4. Hence the expression captures the difference in efficiency between surviving and non-surviving plants times the fraction of initial assets (of firms remaining in each Census year) contributed by the inefficient plants. The coefficients, of course, vary by cohort.

$$I_{j,t} = \sum_{z=1}^{\infty} \frac{Q_{j,z,t} \left(S_{t+5(j-1+z),t} - S_{t+5(j+z),t} \right)}{S_{t+5(j-1),t}}, \tag{9}$$

where $I_{j,t}$ is an index that measures the weighted loss in output per unit of combined inputs that would occur if inefficient plants that survived the j^{th} Census year following their birth at t had retained their market share beyond the j^{th} point in time. The weights are fractions of initial assets contributed by plants that survived to the previous Census year but failed to survive to the next one.

$I_{j,t}$ may be viewed as a weighted inefficiency index that measures a hypothetical loss of productivity. The loss would follow if the survival of old plants, the efficient and the inefficient, were protected by an umbrella such as could be provided by a cartel, by government restrictions on entry, or by public subsidies. Table 5 shows that the loss in productivity if all plants had survived for 10 years would have been roughly 6% for the 1972 entry cohort when compared with the baseline plants, namely those that survived only five years. This translates to about a 1% loss per year. The hypothetical rate of loss is roughly the same (slightly more than 1% per year) for the 1982 entry cohort and slightly lower (namely 0.7%) for the 1977 entrants. An additional loss (depending on cohort) of 0.4-0.9% per year relative to the ten year baseline is shown if plants that did not survive beyond ten years had remained alive. In sum, a substantial fraction of the gain in productivity in the manufacturing sector of the U.S. economy would have been lost if the demise of the inefficient plants were prevented through the fifteenth year of their life.

Beyond fifteen years the impact for productivity of non-survival diminishes and becomes negative beyond the twentieth year. Statistically, both results are a consequence of the fact that γ for twenty-five year survival is lower than that for both twenty and fifteen year survival. Hence, the average initial productivity of plants remaining after fifteen years of life was no better than that for plants which survived to year fifteen but not beyond. The average for those remaining after fifteen years was pulled down by plants surviving twenty-five years even though γ corresponding to twenty-year survival was substantially above that for fifteen years.

Substantively, this result is plausible. Survival beyond twenty years is far less likely to be an indicator of managerial quality at time of birth of the plant since by year twenty-five there may have been several generations of successor managers. We suspect the results would have been quite different if we compared productivity in year fifteen for plants that did and did not survive to year twenty-five.

There is an additional statistical consideration. Information on the longest-lived plants was limited to the 1973-75 cohort (estimates applicable to entry in 1972) and the sample for twenty-five year plants was also fairly thin. Thus estimates for these plants are less reliable than for the larger samples that included plants with shorter life spans.

VII. Conclusions

The results of our study may be summarized as follows:

(a) We developed an index for initial managerial endowments for plants that is independent of their initial performance.

(b) This made it possible for us to estimate the effect of superior managerial endowments on initial productivity.

(c) These estimates indicate that output per unit of combined inputs would have grown substantially less in the U.S. manufacturing sector if all plants, including the inefficient ones, had been assured of survival. This result probably contributes to explaining stagnant productivity growth in economies where firms are protected from competition and hence from their demise.

(d) Managerial learning and average managerial efficiency rise with the age of plants. This partially offsets the advantage that newer plants have because of the later vintage of their capital. These partially offsetting effects contribute to leveling the playing field for competition between old and new plants.

(e) An important result is the substantial effect for productivity of a market for managerial resources internal to the firm. Internal reallocation of resources appears to contribute significantly to efficiency. Thus organizational structures that facilitate such reallocation are important.

(f) Multi-establishment organization encompasses various types of diversification, of which product diversification is but one form. It therefore enhances opportunities for intra-firm reallocation of resources.

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